ISSN: 1849-5931
ISSN: 1849-6148 (Online)



BUSINESS LOGISTICS IN MODERN MANAGEMENT

Proceedings of the 25th International Scientific Conference

EFOS
Faculty of Economics and Business in Osijek

JOSIP JURAJ STROSSMAYER UNIVERSITY IN OSIJEK

Osijek, Croatia 2025

JOSIP JURAJ STROSSMAYER UNIVERSITY OF OSIJEK
FACULTY OF ECONOMICS AND BUSINESS IN OSIJEK

Proceedings of the 25th International Scientific Conference

BUSINESS LOGISTICS IN MODERN MANAGEMENT

October 2-3, 2025

Osijek, Croatia

Published by

Josip Juraj Strossmayer University of Osijek
Faculty of Economics and Business in Osijek

For the Publisher

Sunčica Oberman Peterka, Dean of the Faculty of Economics and Business in Osijek

Editor

Davor Dujak, Josip Juraj Strossmayer University of Osijek, Croatia

Editorial Board

Borna Debelić, University of Rijeka, Croatia
Pavel Foltin, University of Defence, Czech Republic
Jelena Franjković, Josip Juraj Strossmayer University of Osijek, Croatia
Jozef Gašparík, University of Žilina, Slovakia
Alexander Hübner, Technical University of Munich, Germany
Borut Jereb, University of Maribor, Slovenia
Adam Kolinski, Poznan School of Logistics, Poland
Josip Mesarić, Josip Juraj Strossmayer University of Osijek, Croatia
Kristina Petljak, University of Zagreb, Croatia
Vojko Potočan, University of Maribor, Slovenia
Zdenko Segetlija, Josip Juraj Strossmayer University of Osijek, Croatia
Volker Trauzettel, University of Pforzheim, Germany
Katija Vojvodić, University of Dubrovnik, Croatia

Technical Editor

Jelena Franjković

Cover Design

Neno Radić

UDK: 65.012.34
ISSN: 1849-5931
ISSN: 1849-6148 (Online)

Reviewers

Tina Cvahte Ojsteršek, Slovenia
Marjan Sternad, Slovenia
Matevž Obrecht, Slovenia
Pavel Foltin, Czech Republic
Volker Trauzettel, Germany
Adam Kolinski, Poland
Jacek Krzywy, Poland
Joanna Małecka, Poland
Michal Adamczak, Poland
Karolina Kolinska, Poland
Roman Domanski, Poland
Malgorzata Kozlowska, Poland
Arkadiusz Kawa, Poland
Barbara Galińska, Poland
Wiktor Zuchowski, Poland
Agnieszka Tubis, Poland
Łukasz Hadaś, Poland
Mateusz Wiliński, Poland
Attila Turi, Romania
Marinko Maslaric, Serbia
Judit Nagy, Hungary
Norina Szander, Hungary
Nataša Moreti, Croatia
Goran Đukić, Croatia
Ivan Kristek, Croatia
Drago Pupavac, Croatia
Helena Štimac, Croatia
Katija Vojvodić, Croatia
Davor Dujak, Croatia
Ivana Martinčević, Croatia
Aleksandar Erceg, Croatia
Ana Pap Vorkapić, Croatia
Dario Šebalj, Croatia
Ana Živković, Croatia
Dražen Novaković, Croatia
Sofija Turjak, Croatia
Jelena Franjković, Croatia

Organizing Committee

Davor Dujak, Croatia
Jelena Franjković, Croatia
Adam Kolinski, Poland
Katija Vojvodić, Croatia
Kristina Petljak, Croatia
Judit Nagy, Hungary
Péter Bajor, Hungary
Borna Debelić, Croatia
Boris Crnković, Croatia
Marjan Sternad, Slovenia
Roman Domanski, Poland
Ömer Faruk Görçün, Turkey
Hrvoje Serdarušić, Croatia
Domagoj Sajter, Croatia
Dubravka Pekanov, Croatia
Karolina Kolinska, Poland
Dario Šebalj, Croatia
Ana Živković, Croatia
Mladen Pancić, Croatia
Adi Alić, Bosnia and Herzegovina
Dejan Mirčetić, Serbia
Ahmet Mehić, Germany

C O N T E N T

C O N T E N T I

Foreword V

I. TRANSPORTATION AND WAREHOUSING TRENDS 1

João Lemos Nabais, Carlos Manuel de Oliveira Batista, Raquel Ferreira Pereira and Marina Gonçalves (Portugal)
CONTAINER INTERMODAL TRANSPORT ALONG THE ATLANTIC CORRIDOR WITH SUSTAINABLE AWARENESS USING A DIGITAL TWIN . 3

Shahenda Haraz, May SalahEldien and Ahmed Barakat (Egypt)
A REVIEW ON THE ROLE OF AIRPORT SUSTAINABILITY ON AIRPORT PERFORMANCE TO ENHANCE THE AIRPORT RANKING: A SYSTEMATIC LITERATURE REVIEW 25

Nataša Moreti (Croatia)
AIR TRAVEL FOR ALL – THE ACCESSIBILITY OF AIRPORTS 49

Kitti Udvardy, Tamás Bódis and Péter Földesi (Hungary)
ENHANCING WAREHOUSE EFFICIENCY THROUGH SELF-ADAPTIVE BACTERIAL MEMETIC ALGORITHMS 79

Miljenko Mustapić, Dean Hrastić, Nikola Biškup and Nives Domjan Kačarević (Croatia)
WAREHOUSE LOGISTICS PRACTICES IN ENERGY EFFICIENCY AND AUTOMATION: A CASE STUDY OF CROATIAN ENTERPRISES 97

Biljana Činčurak Erceg, Gulesin Sena Das and Aleksandar Erceg (Croatia; United Kingdom)
INDUSTRIAL SYMBIOSIS: SYNERGY OF TRANSPORTATION AND LOGISTICS 111

II. ANALYTICAL APPROACHES TO SUPPLY CHAIN AND TRANSPORT CHALLENGES 133

Radojko Lukić and Blaženka Hadrović Zekić (Serbia; Croatia)
COMPARATIVE ANALYSIS OF TRANSPORT AND STORAGE PERFORMANCE IN THE COUNTRIES OF THE EUROPEAN UNION AND SERBIA BASED ON FUZZY SWARA AND MARCOS METHODS 135

Drago Pupavac (Croatia)
SUPPLY CHAIN OPTIMIZATION MODEL IN CONDITIONS OF GLOBAL INSTABILITY 153

Patrycja Guzanek and Anna Borucka (Poland)
DEMAND FORECASTING IN RELATION TO THE DIVERSITY OF PRODUCT CHARACTERISTICS 169

Ola Qasseer, Péter Bajor and Norina Szander (Hungary)
MEASURING WHAT MATTERS: METHODOLOGICAL CHALLENGES IN DEVELOPING KEY PERFORMANCE INDICATORS FOR SUSTAINABLE INLAND WATERWAYS PROJECTS IN EUROPE 195

III. PERFORMANCE AND INNOVATION IN RETAIL AND AUTOMOTIVE LOGISTICS 211

Łukasz Hadaś, Roman Domański, Hubert Wojciechowski and Tomasz Brzęczek (Poland)
OMNICHANNEL RETAILING: IDENTIFYING THE MOST POPULAR SHOPPING PATHS ACROSS PRODUCT CATEGORIES – THE CONTEXT OF YOUNG POLISH CONSUMERS 213

Attila Turi (Romania)
ECONOMIC IMPACT BEYOND FACTORY GATES: FORD OTOSAN'S INTERMODAL LOGISTICS IN THE ROMANIAN AUTOMOTIVE INDUSTRY 233

Ashrakat Osama and Khaled El Sakty (Egypt)
INVESTIGATING THE ROLE OF OMNICHANNEL STRATEGY IN ENHANCING SUPPLY CHAIN RESILIENCE FROM A CUSTOMER-CENTRIC PERSPECTIVE 251

IV. POLICY AND SUSTAINABILITY CHALLENGES IN SUPPLY CHAIN MANAGEMENT 277

Tamás Bódis, Polina Görbe and Márk Bata (Hungary)
ANALYSIS OF THE LOGISTICAL CHALLENGES OF WASTE RECYCLING THROUGH SIMULATION-BASED ASSESSMENT 279

Damian Dubisz, Arkadiusz Kawa and Rafał Rokicki (Poland)
SIMULATION OF REVERSE WOOD BIOMASS SUPPLY CHAINS FOR EMISSION-EFFICIENT LOGISTICS SCENARIOS 295

Arkadiusz Kawa (Poland)
SUSTAINABLE WOOD BIOMASS SUPPLY CHAIN IN A CIRCULAR ECONOMY: INSIGHTS FROM EMPIRICAL RESEARCH 311

Nikola Drašković, Jasminka Samardžija and Vitomir Pavičić (Croatia)
THE IMPACT OF TARIFFS ON SUPPLY CHAINS AND INNOVATION IN THE TECHNOLOGY INDUSTRY: A THEORETICAL REVIEW 333

Veljko Mijušković, Slobodan Aćimović, Ana Todorović Spasenić and Nikola Milošević (Serbia)
THE IMPACT OF US CUSTOMS POLICY ON SUPPLY CHAIN MANAGEMENT OF THE SERBIAN COPPER PROCESSING INDUSTRY 349

Sanja Bojić, Marinko Maslaric, Gabriel Fedorko, Svetlana Nikolicic and Dejan Mirčetić (Serbia, Slovakia)
DEVELOPING CROSS-BORDER GUIDELINES FOR SMEs' SMART SPECIALISATION: THE CASE OF THE DANUBE REGION 363

V. HUMAN AND ORGANIZATIONAL ASPECTS OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT 381

Zsófia Jámbor, Borbála Szüle, Anna Freund and Judit Nagy (Hungary)
THE ROLE OF RELATIONSHIP MANAGEMENT IN LEARNING FROM SUPPLY CHAIN PARTNERS: AN EMPIRICAL ANALYSIS OF SECTORAL, REGIONAL AND SIZE EFFECTS 383

Vesna Sesar, Ana Globočnik Žunac and Dinko Primorac (Croatia)
INTANGIBLE ASPECTS- COMMUNICATION AND EMPLOYEE PERFORMANCE IN LOGISTIC COMPANIES 401

Adrienn Munkácsi and Barbara Kirchner (Hungary)
CHALLENGES FACED BY RECENT GRADUATES IN SUPPLY CHAIN MANAGEMENT 419

VI. LOGISTICS BEYOND BUSINESS 437

Jozef Gašparík, Zdenka Bulková, Vladislav Zitrický and Borna Abramović (Slovakia, Croatia)
INTEGRATION OF ADVANCED PASSENGER APPLICATION FEATURES INTO URBAN MOBILITY LOGISTICS 439

Jakob Grubmüller, Maike Overmeyer, Sascha Düerkop and Leon Pradella (Germany)
THE ECONOMICAL APPLICATION OF CARGO BIKES IN LOGISTICS – OVERVIEW OF CURRENT UTILIZATION AND RELATED BUSINESS MODELS 461

Ondřej Novosad, Markéta Pětová and Pavla Davidová (Czech Republic)
HOW STORAGE AFFECTS THE QUALITY OF MILITARY EQUIPMENT IN THE CONTEXT OF THE CZECH ARMY 479

Markéta Pětová, Ondřej Novosad, Martin Novotný and Milan Vábek (Czech Republic)
COMBAT RATIONS SUPPLY CHAIN IN THE CZECH ARMY 491

Radka Lopourová, Michal Kovařík, Filip Dohnal, Milan Vábek and Jan Kotisa (Czech Republic)
LOCATING AMMUNITION DEPOTS: MULTI-CRITERIA GIS APPROACH IN THE CZECH REPUBLIC 507

Noemi Piricz (Hungary)
THE CHANGING ROLES OF UTILITIES IN SMART GRIDS 527

VII. TECHNOLOGY IN LOGISTICS 535

Katerina Fotova Čiković, Goran Kozina and Ivana Martinčević (Croatia)
APPLICATION OF ARTIFICIAL INTELLIGENCE IN SUPPLY CHAIN MANAGEMENT: BIBLIOMETRIC ANALYSIS IN BUSINESS, MANAGEMENT AND ACCOUNTING 537

Marta Waldmann and Adam Koliński (Poland)
IMPACT OF DIGITALIZATION OF LOGISTICS PROCESSES THROUGH THE NEW SILK ROAD ON SUPPLY CHAIN RESILIENCE 555

Zsófia Jámbor, Borbála Szüle, Judit Nagy and Anna Freund (Hungary)
DO DIGITALIZATION EFFORTS RESULT IN SUPPLY CHAIN PROCESS DEVELOPMENT? AN EMPIRICAL ANALYSIS OF HUNGARIAN FIRMS ... 575

DO DIGITALIZATION EFFORTS RESULT IN SUPPLY CHAIN PROCESS DEVELOPMENT? AN EMPIRICAL ANALYSIS OF HUNGARIAN FIRMS

Zsófia Jámbor
Corvinus University of Budapest, Institute of Operations and Decision Sciences, Department of Supply Chain Management, Hungary
E-mail: zsofia.jambor@uni-corvinus.hu

Borbála Szüle
Corvinus University of Budapest, Institute of Operations and Decision Sciences, Department of Operations Research and Actuarial Sciences, Hungary
E-mail: borbala.szule@uni-corvinus.hu

Judit Nagy
Corvinus University of Budapest, Institute of Operations and Decision Sciences, Department of Supply Chain Management, Hungary
E-mail: judit.nagy@uni-corvinus.hu

Anna Freund
Corvinus University of Budapest, Institute of Operations and Decision Sciences, Department of Supply Chain Management, Hungary
E-mail: anna.freund@uni-corvinus.hu

Received: July 11, 2025
Received revised: August 21, 2025
Accepted for publishing: September 16, 2025

Abstract

When used effectively, various digitalization tools can improve companies' performance and responsiveness to external disruptions and negative events. However, if they are used without the right expertise or are not used effectively, they waste scarce resources which leads to declining firm performance and competitiveness. The aim of this study is to outline a research framework in which it can be examined whether digitalization efforts result in supply chain process development. Survey data with responses from 335 Hungarian medium sized and large firms are analysed with regression modelling. Empirical findings highlight a positive association between digitalization efforts and supply chain process development. Regression results also reveal that at different quantile values there is heterogeneity in this effect so that digitalization effort may have a larger effect if the supply chain process development is relatively low. These results also highlight the importance of digitalization in supply chain development.

Keywords: digitalization effort, process development, supply chain management

1. INTRODUCTION

In our current era marked by rapid technological change and frequent disruptions, firms increasingly turn to digitalization as a strategic lever to enhance responsiveness, efficiency and resilience across their supply chains. Drawing on the dynamic capabilities perspective, which emphasises a firm's ability to integrate, build and reconfigure competencies in response to environmental shifts (Teece et al., 1997; Bag et al., 2020), scholars have begun to unpack how digital tools (ranging from advanced analytics to Industry 4.0 technologies) are shaping operational and strategic outcomes (Eslami et al., 2021; Hautala-Kankaanpää, 2022). Yet, despite widespread adoption, questions remain about whether investments in digitalization translate into tangible improvements in supply chain process development or merely represent costly initiatives that fail to yield sustained benefits.

Supply chain process development encompasses both disruptive innovations (such as the deployment of cutting-edge technologies) and incremental enhancements through continuous improvement practices (Acar & Uzunlar, 2014; Boon-itt et al., 2017). Prior academic work suggests that digital platforms may act indirectly, by strengthening underlying process capabilities like information sharing, coordination and responsiveness, rather than driving performance directly (Hautala-Kankaanpää, 2022). The effectiveness of digitalization efforts often hinges on contextual factors, including organisational culture, resource allocation and top-management commitment (Kane et al., 2017; Szukits, 2022). Yet empirical evidence linking digitalization efforts to process development remains fragmented, particularly when accounting for heterogeneous effects across firms with varying baseline process maturity.

The aim of this paper is twofold. On the one hand, to propose an integrative framework that positions digitalization efforts as antecedents of supply chain process development, mediated by both technological and organisational capabilities. On the other hand, to empirically test this framework using survey data from 335 Hungarian medium-sized and large firms. By employing regression analyses, we explore not only the overall association between digitalization effort and process development but also how this relationship varies across different levels of process maturity. Our findings offer practical insights for managers seeking to prioritise digital investments and for researchers aiming to deepen the theoretical understanding of digital transformation in supply chain contexts. In our research we seek to answer the following research question: **to what extent do company's digitalization effort influence their supply chain process developments?**

Hungary is a small, open economy with a substantial manufacturing base and strong integration into regional value chains. Medium and large firms in this context are the main adopters of capital-intensive digital technologies and often function as coordination hubs in supplier networks. Focusing on this firm segment reduces size-related heterogeneity and cross-country institutional noise, helping to isolate how variation in digitalization effort maps onto process development while offering insights relevant to similar transition and small open economies.

This study offers immediate practical value for managers of Hungarian medium and large firms by identifying where digital investments most reliably translate into

measurable process improvements (improved information visibility, coordination, and targeted automation) and so helps prioritise pilots and upskilling. Theoretically, it contributes by revealing distributional heterogeneity in digitalization effects (via quantile regression), challenging one-size-fits-all prescriptions and linking digital effort to baseline process capability.

The paper will be built up as follows. After the introduction section we collect the main theoretical contributions including company capabilities, digitalization efforts and supply chain process development in Section 2. In Section 3 we turn to the aim of the current study and the hypothesis development, followed by a presentation of both the data and the research methodology in Section 4. In Section 5 we share the main results, in Section 6 we interpret our result in context of the existing literature. In the final section (Section 7) we draw the conclusions and formulate directions for future research.

2. LITERATURE REVIEW

2.1 Company Capabilities

In the literature, dynamic capabilities are recognised as essential drivers of supply chain transformation in the digital era. Rooted in Teece et al.'s (1997) theory, dynamic capabilities refer to a firm's ability to integrate, build and reconfigure internal and external competencies to address rapid environmental changes. This concept is used in empirical works by Bag et al. (2020), Zouari et al. (2020) and Jambor and Nagy (2022), all of which highlight technological, organizational and strategic capabilities - such as flexibility, sensing and integration - as crucial enablers of digitalization in supply chains. These studies collectively affirm that such capabilities not only improve operational efficiency but are also indispensable for achieving agility, resilience and sustained competitive advantage.

Despite the overall consensus, the literature diverges in how it conceptualizes and operationalizes company capabilities. While Bag et al. (2020) and Zouari et al. (2020) take a structured, measurable approach using constructs such as digital maturity and technological adoption, Eraut (1998) challenges this by framing competence as both socially constructed and individually situated. Eraut's approach critiques the reduction of competence to technical indicators and insists on understanding it as a negotiated and context-dependent phenomenon. This philosophical divergence reveals a gap between theoretical abstraction and empirical application—particularly regarding how capabilities are measured and developed within varying organizational settings.

The reviewed works also reveal an evolution in the understanding of capabilities, from theoretical models to empirically grounded frameworks. Teece et al. (1997) introduced the concept within strategic management, emphasizing path dependency and organizational routines. Building on this, Bag et al. (2020) and Zouari et al. (2020) classify capabilities into specific domains and link them with digital tool adoption and supply chain resilience. Jambor and Nagy (2022) extend this perspective by integrating the dimensions of sensing, absorptive, integrative and relational

capabilities, effectively translating abstract theoretical constructs into tangible managerial practices. Over time, the literature shifted from broad theorizing to more granular, practice-oriented analysis, albeit with limited acknowledgment of social or institutional factors. Therefore, Ellström et al. (2022) emphasize in their study that dynamic capabilities - such as knowledge integration and adaptability - play a key role in enabling companies to successfully implement digital transformation and thereby achieve long-term competitive advantage.

From these sources, it can be concluded that company capabilities form the cornerstone of successful digital transformation initiatives in supply chains. Firms that excel at sensing environmental shifts, learning from disruptions and reconfiguring processes are more likely to leverage digital tools effectively and achieve resilient operations. Organizational learning, collaborative culture and top-management commitment repeatedly emerge as critical success factors. Capabilities are thus not merely supporting elements but strategic assets in building adaptive and future-proof supply chains.

Current studies often treat capabilities as static, measurable entities rather than dynamic (Hirvonen & Majuri, 2020; Savastano et al., 2022; Teece, 2020), evolving processes shaped by organizational context and feedback. There is limited understanding of how capability development unfolds over time or varies across industries.

2.2 Digitalization Efforts

Digitalization serves as a critical enabler of enhanced supply chain capabilities. Eslami et al. (2021) emphasize the moderating role of Industry 4.0 technologies in amplifying the performance outcomes of supply chain agility (SCA), particularly in dynamic manufacturing contexts. They argue that digital technologies enhance responsiveness and visibility - core elements of SCA - which in turn lead to superior financial performance. Similarly, Hautala-Kankaanpää (2022) focuses on how digital platforms enable supply chain capabilities such as information exchange, integration and responsiveness, which subsequently drive operational performance. Her findings support a mediation model where digital platforms do not directly enhance performance but rather act through the intermediary of strengthened supply chain capabilities.

The direct impact of digital technologies is not clear. Eslami et al. (2021) find that Industry 4.0 technologies do not moderate the relationship between supply chain integration and agility but do positively moderate the link between agility and financial performance. This suggests that digital tools alone are insufficient to translate integration into agility unless organizations already possess the conditions to capitalize on them. Conversely, Hautala-Kankaanpää (2022) reports a negative direct effect of digital platforms on operational performance, explained by the mediating effect of supply chain capabilities. Notably, she introduces digital culture as a contextual moderator, finding that a firm's cultural openness to digital technologies significantly influences the performance outcomes of digital platform adoption. They agree that digital tools are not valuable in isolation; their impact depends on firm-level

capabilities to integrate, interpret and act upon digital information. The capability-focused literature (e.g., Teece et al., 1997, Bag et al. 2020, Zouari et al. 2020, Jambor & Nagy 2022) reinforces this, too, showing that digital technologies alone do not generate performance gains unless accompanied by dynamic capabilities such as sensing, learning and integration. While Eslami et al. (2021) and Hautala-Kankaanpää (2022) primarily examine operational and financial performance, literature expands this by including resilience, flexibility and long-term adaptability - suggesting that digital success should be evaluated not only by immediate returns but by its contribution to strategic transformation. Furthermore, Hirvonen and Majuri (2020) indicate that developing the digital capabilities of manufacturing SMEs - including the introduction of data-driven decision support systems and process automation - contributes significantly to increasing operational efficiency and innovation potential.

Eslami et al. (2021) conceptualize supply chain agility as a higher-order dynamic capability supported by digital tools in turbulent environments, while Hautala-Kankaanpää (2022) aligns by treating supply chain capability as a mediating resource that unlocks value from digital platforms. Both argue that value realization depends on the firm's ability to embed digital tools into adaptive routines and collaborative networks.

2.3 Supply Chain Process Development

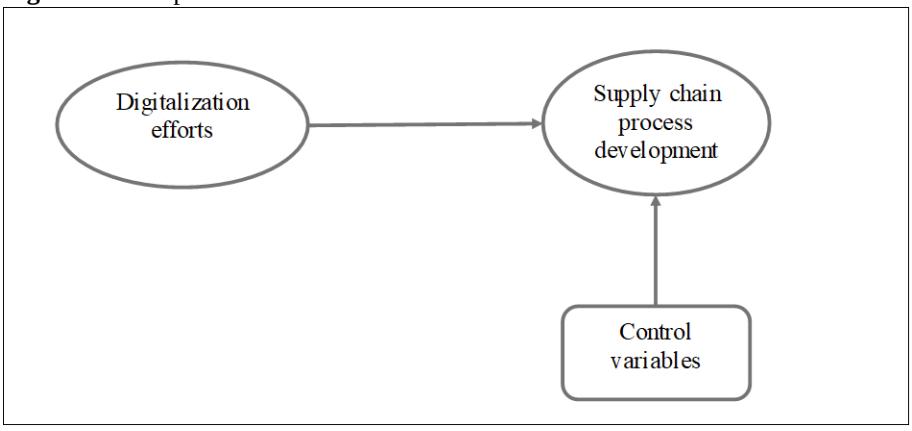
Boon-itt (2017) identifies supply chain process capabilities - particularly information sharing, integration, coordination and responsiveness - as essential mechanisms for improving both operational and strategic performance, emphasizing their dynamic and mutually reinforcing nature. This perspective aligns with earlier digitalization research showing that technologies enhance these same capabilities, notably supporting Eslami et al.'s (2021) view of agility as a dynamic capability. Complementing this, Acar and Uzunlar (2014) provide empirical evidence from the Turkish furniture sector demonstrating that information technology (IT) and process development (PD) efforts individually and jointly drive improvements in time-based supply chain performance. Their findings highlight the synergistic effects between IT and PD, reinforcing the notion from Hautala-Kankaanpää (2022) that digital tools alone cannot guarantee performance gains without being embedded in a robust capability framework. Adding a methodological layer, Korpela et al. (2001) introduce the Analytic Hierarchy Process (AHP) as a strategic decision-making tool within the PROPER business process redesign framework, offering a systematic approach to prioritize and align supply chain development initiatives with organizational goals. Together, these studies underscore that digital tools are only as effective as the organizational and processual structures supporting them. They collectively reinforce the argument that successful digital transformation requires integrated, capability-driven process development strategies, supported by data-informed decision-making frameworks like AHP. Savastano et al. (2022) highlight in their empirical study that the interaction between digital manufacturing and dynamic capabilities can directly and indirectly improve the efficiency of supply chain process development, especially when the company is able to respond flexibly to market changes. Ultimately, supply chain process development emerges not merely as an operational concern but as a

strategic lever for agility, resilience and competitive advantage in digitally transforming environments.

3. Formulating the Research Goal and Hypothesis Development

Based on the reviewed literature, this study aims to explore how digitalization efforts influence firm performance through the lens of supply chain management, focusing in particular on the mediating role of supply chain process development. Prior research has established that dynamic capabilities such as sensing, learning and integration are crucial for translating digital investments into meaningful performance outcomes. However, digital tools alone often do not yield direct gains unless embedded within robust organizational contexts, as highlighted by the contrasting findings of Eslami et al. (2021) and Hautala-Kankaanpää (2022). Similarly, studies by Acar and Uzunlar (2014) and Boon-itt (2017) demonstrate that the interplay between information technology and process development enhances time-based performance, suggesting a critical mediating role of supply chain processes. According to Savastano et al. (2022), Ellström et al. (2022) and Hirvonen and Majuri (2020) the combined examination of supply chain process development, corporate capability enhancement and digitalization efforts enables companies to develop complex and sustainable competitive advantages in a rapidly changing business environment. Therefore, this research seeks to explore the relationship between digitalization efforts and supply chain process development with company capabilities as contextual enablers. Special attention will be given to differences between large enterprises and SMEs within the Hungarian business environment, contributing to a better understanding of digital transformation in supply chains. The conceptual research model is illustrated in Figure 1.

Figure 1 Conceptual research model



Source: authors' own construction

Figure 1 illustrates our conceptual model. Digitalization effort is the core antecedent driving supply chain process development, shown by the primary pathway. IT integration capability and top-management commitment are considered as moderators that amplify the effort–development link, while process maturity enters as a conditional factor influencing the strength of this relationship across different performance quantiles. In the following the research hypothesis about the relationship between digitalization efforts and supply chain process development is examined.

4. DATA AND RESEARCH METHOD

4.1 Data

The analysis is based on survey data from the Competitiveness Research Center (CRC) at Corvinus University of Budapest which is a periodic survey of Hungarian firms since 1996. Data collection was performed at the end of 2024 and at the beginning of 2025, and the dataset contains responses about 335 Hungarian medium-sized and large firms with at least 50 employees. Table 1 summarizes the main descriptive statistics.

The recent wave (seventh) involved face-to-face interviews conducted from end of 2024 through beginning of 2025, Table 1 shows the main descriptive statistics of the sample. The purposes of this study (examining how the quality of relationships between supply chain partners influences the degree of mutual learning and cooperation) we conducted our analysis to the 335 companies (Hungarian medium-sized and large firms with at least 50 employees, selected from the total Hungarian population of 3748 companies) in the dataset.

The latest competitiveness questionnaire drew heavily on previous surveys, which were revised, updated and methodologically improved by a group of experts set up at the request of the CRC. The perception-based questionnaire comprised approximately 600 items organized into one single questionnaire covering corporate strategy and key functional areas like production, marketing, finance, human resource and leadership management, supply chain management, digitalization etc.).

Table 1 Descriptive statistics

	Frequency	**Percent (%)**
Region		
Budapest (capital city)	122	36.4
Other	213	63.6
Firm size		
Medium-sized	292	87.2
Large	43	12.8
Sector		

Manufacturing	164	49.0
Other	171	51.0

Source: authors' calculations

As seen in Table 1, most firms are medium sized with number of employees between 50 and 250 (87.2%), while the other firms may be classified as large based on the number of employees (12.8%). Manufacturing sector represents 49% of respondents, and 36.4% of the firms are located in the capital city.

4.2 Methodology

When providing answers to questions during data collection, respondents were asked to evaluate how much they agree with statements, with possible answers ranging from "not at all" (indicated by 1) to "completely" (indicated by 5). The digitalization efforts indicators are inspired by previous literature (e.g. Kane et al., 2017; Szukits, 2022), while the supply chain process development indicators are based on previous qualitative research performed by three of the authors.

Table 2 shows the survey questions related to digitalization efforts and supply chain process development. The below listed statements holistically capture the strategic, procedural, and resource dimensions essential to a firm's digitalization efforts. Assessing whether a company has a clear and coherent digital transformation strategy (1. a) ensures that stakeholders understand the organisation's overarching digital vision and priorities. Evaluating the presence of a defined process for initiating and implementing digitalization projects (1. b) highlights the company's ability to move from strategy to execution in a systematic, repeatable way. Measuring the adequacy of financial resource allocation (1. c) confirms whether digital initiatives are truly supported and not merely lip service, which is critical for sustainable transformation. Together, these items differentiate firms that merely talk about digitalization from those that have embedded it into their strategic planning, governance and budgeting practices. They also enable benchmarking across organisations, revealing strengths and pinpointing gaps in leadership alignment, operational readiness and investment commitment. By covering strategy, process and funding, the survey questions provide a balanced view of digital maturity without overloading respondents with technical detail. Finally, their simplicity facilitates clear self-assessment and comparability, driving focused discussions on where to accelerate or refine the digital agenda.

Table 2 Digitalization and supply chain process development related questions of the questionnaire

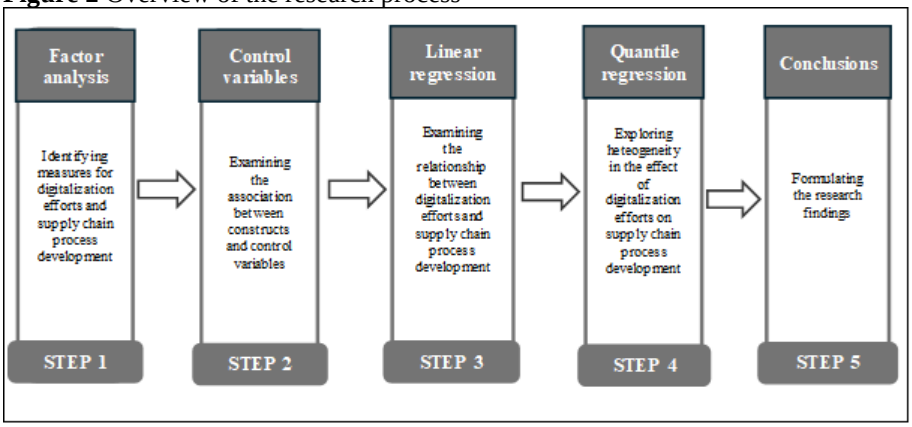
Digitalization and supply chain management sections of the questionnaire	**Likert scale (1-5)**	**Statements**
1.How valid are the following statements for your company?	1 – not at all 3 – moderately 5 – completely	a) Our company has a clear and coherent digitalization (digital transformation) strategy. b) We have a clearly defined process for initiating and implementing digitalization projects. c) We allocate sufficient financial resources to our digitalization strategy and its implementation.
2.Please rate how true the following statements are for your company's operations!	1 – not at all 3 – somewhat 5 – completely	a) We develop innovative technologies to improve our operations. b) We effectively use tools for continuous improvement.

Source: authors' construction

The questions included in the survey effectively capture both the innovation and the continuous refinement aspects that underpin strong supply chain process development. Assessing whether a company develops innovative technologies (2. a) highlights its commitment to pioneering new methods, automation, and cutting-edge solutions that can drive step-changes in efficiency and responsiveness. Measuring the use of continuous improvement tools (2. b) reveals how systematically the firm pursues incremental gains through methodologies (like lean, six sigma, or kaizen) ensuring that processes evolve rather than stagnate. Together, they distinguish organisations that merely maintain the status quo from those actively investing in breakthrough technologies while also embedding a culture of ongoing refinement. These dual lenses (namely innovation and continuous improvement) provide a balanced view of both disruptive and incremental capabilities in process development. They enable benchmarking across peers, indicating whether a firm excels at big investments on new technologies or focuses on operational excellence through steady,

data-driven enhancements. Their simplicity makes them easy for respondents to self-assess while still surfacing core strengths and weaknesses in process-oriented mindsets. Ultimately, they help identify where to allocate resources, whether toward experimenting with new digital tools or deepening existing improvement practices. The empirical analysis includes these variables to examine the research questions. The main steps in the research process are illustrated by Figure 2. During the research process, first digitalization efforts and supply chain process development are measured, then (after exploring association with control variables) the relationship between these variables is examined with regression modeling.

Figure 2 Overview of the research process



Source: authors' own construction

To measure digitalization efforts and supply chain process development, exploratory factor analysis (based on principal component analysis) is performed, the main results are summarized in Table 3.

Table 3 Summary of measures

	loading	TVE	KMO	Cronbach's alpha
DIGITALIZATION EFFORT		*0.728*	*0.708*	*0.812*
Our company has clear and coherent digitalization (aimed at digital transformation) strategy.	0.837			
We have a clear process for starting and implementing digitalization projects.	0.878			
	0.844			

We assign enough material resources to the digitalization strategy and its implementation.				
SUPPLY CHAIN PROCESS DEVELOPMENT		*0.791*	*0.500*	*0.727*
We develop innovative technologies to develop our operation.	0.890			
We efficiently apply the tools of continuous development.	0.890			

Note: The table contains principal component analysis results (component matrix data, Kaiser-Meyer-Olkin measure of sampling adequacy, and total variance explained for each construct separately) and Cronbach's alpha.
Source: authors' calculations

As seen in Table 3 convergent validity can be considered as adequate, since all loading values are above 0.8. Internal reliability can also be considered adequate because Cronbach's alpha values are above 0.7. In addition to the variables measuring digitalization efforts and supply chain process development, the empirical analysis includes binary variables indicating whether the firm is located in the capital city, whether the firm can be classified as large firm (based on the number of employees), and whether the firm belongs to manufacturing sector.

5. RESULTS

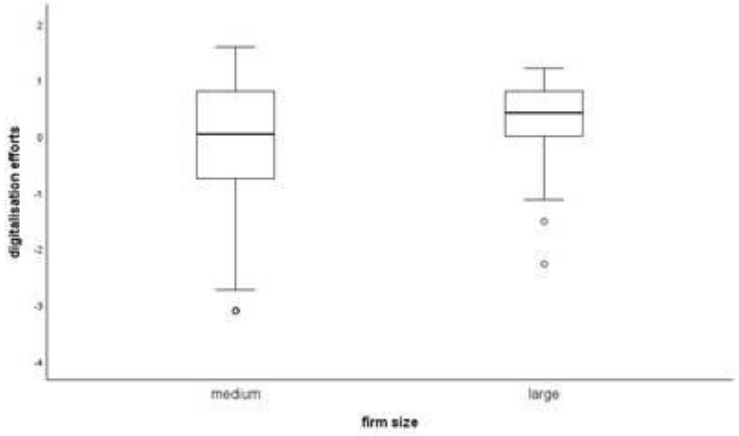
The key research question of the paper is associated with the relationship between digitalization efforts and supply chain process development. This relationship is examined with regression modelling, and the calculations have been performed with IBM SPSS Statistics Version 29.0.

Linear regression can reveal insights into the relationship between digitalization efforts and supply chain process development. Since it is possible that this relationship is also influenced by other factors, simple and multiple linear regression results are compared. Previous literature suggests that supply chains can be influenced by regional (Melkonyan et al., 2019), sectoral (Hennequin et al., 2025) and firm size effects (Clohessy & Acton, 2019). Therefore, the binary variables indicating whether the firm is located in the capital city, whether the firm can be classified as large (based on the number of employees) and whether the firm belongs to the manufacturing sector are included as control variables in the multiple regression model.

It can be tested whether, based on empirical data, digitalization efforts and supply chain process development are associated with the variables indicating regional, sectoral, or firm size differences. To examine these differences, Mann-Whitney test results are calculated. The empirical findings highlight that none of the binary variables indicating location in the capital city (U=12303.5, asympt.p=0.418),

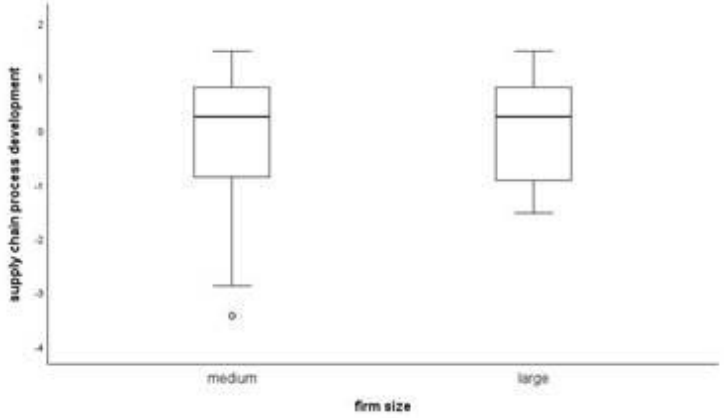
manufacturing sector (U=13143.5, asympt.p=0.320) and large firms (U=5451, asympt.p=0.162) has a statistically significant relationship with the digitalization effort indicator. Similarly, the binary variables indicating location in the capital city (U=12157, asympt.p=0.322), manufacturing sector (U=13507, asympt.p=0.557) and large firms (U=5874.5, asympt.p=0.492) do not have a statistically significant relationship with the supply chain process development indicator. Figure 3 and Figure 4 illustrate these findings with the binary variable indicating large firms.

Figure 3 Firm size effects on digitalization efforts



Source: authors' calculations

Figure 4 Firm size effects on supply chain process development



Source: authors' calculations

Although Mann-Whitney test results do not indicate a significant association between the digitalization efforts and supply chain process development variables and

the control variables, based on previous literature, the three binary variables related to regional, sectoral and firm size differences are included as control variables in the multiple regression model. Table 4 summarizes the results of the simple and multiple linear regression models.

Table 4 Linear regression results

	Simple model	Extended model
Constant	0.000 (1.000)	-0.073 (0.380)
Digitalization efforts	0.462** (<0.001)	0.457** (<0.001)
Control variables		
Capital city (binary)		0.081 (0.433)
Large firm (binary)		0.036 (0.810)
Manufacturing sector (binary)		0.081 (0.418)
Model fit		
R^2	0.214	0.217
Adjusted R^2	0.212	0.207

Notes: The dependent variable is supply chain process development. The values in parentheses are p-values. The asterisks ** denote statistical significance at the 1 % level.
Source: own calculations

As seen in Table 4, the coefficient of digitalization efforts is statistically significant in both regression models. This result highlights that, based on empirical data, digitalization efforts significantly positively influence supply chain process development. The coefficients of the control variables are not statistically significant, which is in line with the findings about the nonsignificant differences across the binary variable categories indicated by the Mann-Whitney test results.

Linear regression results highlight the significance of the relationship between digitalization efforts and supply chain process development, however, the results do not provide insights into differences across effects on higher or lower levels of supply chain development. To explore heterogeneity in the effect of digitalization efforts on supply chain process development, quantile regression is performed (at the 25%, 50% and 75% quantile values) without control variables. Table 5 presents the estimated effect of the digitalization efforts variable for the 25th percentile, 50th percentile (median) and the 75th percentile. The pseudo R-squared values are 0.154, 0.101 and

0.05 for the quantile regression models for the 25th percentile, 50th percentile (median) and the 75th percentile, respectively.

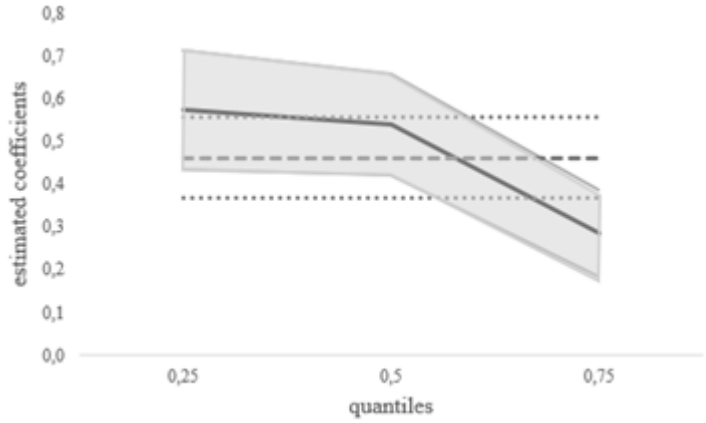
Table 5 Quantile regression results

quantile	coefficient	95% confidence	
		lower bound	upper bound
0.25	0.575** (<0.001)	0.437	0.713
0.50	0.540** (<0.001)	0.420	0.660
0.75	0.286** (<0.001)	0.184	0.387

Notes: The values in parentheses are p-values. The asterisks ** denote statistical significance at the 1 % level.
Source: own calculations

Figure 5 shows how the estimated coefficients at the three quantile values differ from the estimated coefficient belonging to the digitalization efforts variable in the simple linear regression model. In Figure 5, the horizontal axis indicates the quantile scale and the vertical axis indicates the effect of digitalization efforts on supply chain process development so that the values of the estimated coefficient at a given quantile (and the 95% upper and lower bounds indicated by the shaded area) are compared to the coefficient (and the 95% confidence interval) in the simple linear regression model (without control variables).

Figure 5 Comparison of estimated coefficients



Source: authors' own calculations

The pattern in Figure 5 also provides support for the research hypothesis about the association between digitalization efforts and supply chain process development. The findings highlight that although there is heterogeneity in the effect of digitalization efforts on supply chain process development, the estimated coefficients in case of the three quantile values are statistically significant and positive. The empirical results also indicate that, when compared to a lower quantile value, the effect of digitalization efforts on supply chain process development is smaller at higher quantiles of the supply chain process development distribution, suggesting that digitalization efforts may have a more pronounced effect on supply chain process development if the process development level is relatively low. Based on the presented regression results it may be concluded that the empirical findings support the research hypothesis about the positive effect of digitalization efforts on supply chain process development.

6. DISCUSSION

Our results suggest that the relationship between firms' digitalization effort and supply-chain processes is overall positive, yet heterogeneous across process maturity: quantile analysis showed that the effect is stronger at lower baseline process-maturity levels and attenuates for more advanced processes. This points to a mechanism whereby the primary payoff of digital investments often appears as improved information visibility and basic coordination, which can yield rapid gains for organizations that previously lacked informational transparency (Bag et al., 2020; Savastano et al., 2022; Zouari et al., 2021). This observation is consistent with the dynamic capabilities literature (Teece et al., 1997; Ellström et al., 2022), which emphasizes that the effectiveness of technological resources depends critically on the presence of organizational practices, learning mechanisms and governance structures.

A further explanation for the observed heterogeneity is that digitalization alone is rarely sufficient: the scalability and sustainable impact of technological investments require complementary resources — for example, top-management commitment, integration between IT operations and business operations, and organizational competence development (Kane et al., 2017; Eslami et al., 2021; Hautala-Kankaanpää, 2022). Consequently, the diminished marginal effect observed in more advanced processes can be partly explained by the fact that additional digital spending in these contexts tends to focus increasingly on fine-tuning, integration and human–technology collaboration, whose benefits typically materialize over longer horizons and through more structured interventions (Savastano et al., 2022; Bag et al., 2020).

From both theoretical and managerial perspectives, the findings suggest caution against standardized digital investment prescriptions. The results indicate that managements should adopt differentiated strategies: in lower process-maturity areas, quick pilot projects that enhance information visibility and coordination can deliver high returns, whereas in higher-maturity areas efforts should be directed toward

integration, change management and human capability development (Kane et al., 2017; Szukits, 2022). This approach both extends the dynamic capabilities framework (by highlighting the importance of baseline capability and digital effort interactions) and offers practical guidance for prioritisation and scaling of digital transformation initiatives (Melkonyan et al., 2019; Korpela et al., 2001).

7. CONCLUSION

It is of high importance to emphasize the dissemination of an integrated system and process development approach among supply chain actors. Based on the results, it can be concluded that isolated, so-called point-based digitalization efforts should be avoided. This means that the introduction of any new system must be followed by the re-engineering of related processes. It is also key to prioritize the order in which digitalization tools are implemented in order to ensure that the most effective interventions receive funding first.

The success of digitalization efforts is greatly influenced by the state of the organizational culture and the openness or resistance of individual employees to digital developments. Support for digital innovation and continuous development should be included and highlighted in the management incentive system, and change management also plays an important role, as changes cannot happen overnight. Workshops can be developed and organized on a regular basis to showcase good practices and exchange experiences, and it is worth supporting employees with a form of digital mentoring (for example a "digital internal ambassador"). In addition to introducing individual digital tools, it is also very important to emphasize that it is not worth focusing solely on the introduction of technical tools, but that digital skills must also be developed in parallel.

These solutions not only increase the efficiency of supply chain processes in the short term but also lay the foundation for organizational digital maturity and competitiveness in the longer term for the entire supply chain.

Despite its contributions, this study has several important limitations that we cannot ignore when interpreting our results and formulating future research directions. First, the cross-sectional, survey-based design prevents strong causal claims. So observed associations between digitalization effort and process development may reflect reverse causality or omitted confounders. Second, the data rely on single-respondent, perceptual measures collected at one point in time, which raises the possibility of common-method bias and perceptual measurement error. Third, some constructs (most notably the supply chain process development scale) have limited item coverage, reducing construct breadth and calling for more comprehensive measurement in future work. Fourth, the sample is deliberately restricted to medium and large Hungarian firms. While this increases internal comparability, it limits external generalizability to other firm sizes and national contexts.

For future research we formulated three open research questions consolidating and extending our findings. First, what are the long-term impacts of emerging Industry 4.0 technologies on process development beyond initial implementation, do early gains persist, deepen, or dissipate, and which organizational conditions (e.g., governance, resourcing, learning mechanisms) drive these trajectories? Second, how does cross-functional integration (for example, between IT, operations management and marketing) shape the realization, scaling and diffusion of digitalization's benefits across supply chains? Third, how do external ecosystem factors (such as technology vendor networks, industry clusters and regulatory support) interact with firm-level capabilities to enable or constrain sustained digital transformation, and which methodological approaches (for instance longitudinal designs or mixed-methods combining network analysis with interviews) are best suited to uncover these causal and dynamic relationships? Addressing these questions for future research will deepen theoretical understanding and offer actionable insights for managers and policymakers seeking to foster sustained digital transformation in transition and small open economies.

8. REFERENCES

Acar, A. Z., & Uzunlar, M. B. (2014). The Effects of Process Development and Information Technology on Time-based Supply Chain Performance. *Procedia - Social and Behavioral Sciences*, *150*, 744–753. https://doi.org/10.1016/j.sbspro.2014.09.044

Bag, S., Gupta, S., & Luo, Z. (2020). Examining the role of logistics 4.0 enabled dynamic capabilities on firm performance. *International Journal of Logistics Management*, *31*(3), 607–628. https://doi.org/10.1108/IJLM-11-2019-0311

Boon-itt, S., Wong, C. Y., & Wong, C. W. Y. (2017). Service supply chain management process capabilities: Measurement development. *International Journal of Production Economics*, *193*, 1–11. https://doi.org/10.1016/j.ijpe.2017.06.024

Clohessy, T., & Acton, T. (2019). Investigating the influence of organizational factors on blockchain adoption: An innovation theory perspective. *Industrial Management and Data Systems*, *119*(7), 1457–1491. https://doi.org/10.1108/IMDS-08-2018-0365

Ellström, D., Holtström, J., Berg, E., & Josefsson, C. (2022). Dynamic capabilities for digital transformation. *Journal of Strategy and Management*, *15*(2), 272–286. https://doi.org/10.1108/JSMA-04-2021-0089

Eraut, M. (1998). Concepts of competence. *Journal of Interprofessional Care*, *12*(2), 127–139. https://doi.org/10.3109/13561829809014100

Eslami, M. H., Jafari, H., Achtenhagen, L., Carlbäck, J., & Wong, A. (2021). Financial performance and supply chain dynamic capabilities: the Moderating Role of Industry 4.0 technologies. *International Journal of Production Research*, 0–18. https://doi.org/10.1080/00207543.2021.1966850

Hautala-Kankaanpää, T. (2022). The impact of digitalization on firm performance: examining the role of digital culture and the effect of supply chain capability. *Business Process Management Journal*, *28*(8), 90–109. https://doi.org/10.1108/BPMJ-03-2022-0122

Hennequin, T., Hilbers, J. P., Wilting, H. C., Ivanova, O., Kuenen, J. J. P., Hauck, M., van Zelm, R., & Huijbregts, M. A. J. (2025). Greenhouse gas footprints of economic sectors at the subnational European scale. *Journal of Cleaner Production*, *514*. https://doi.org/10.1016/j.jclepro.2025.145761

Hirvonen, J., & Majuri, M. (2020). Digital capabilities in manufacturing SMEs. *Procedia Manufacturing*, *51*, 1283–1289. https://doi.org/10.1016/j.promfg.2020.10.179

Jámbor, Z., & Nagy, J. (2022). Resilience of Food Supply Chains – a Dynamic Capability Approach. *Ekonomska Misao i Praksa*, *31*(2), 473–486. https://doi.org/10.17818/emip/2022/2.6

Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D., & Buckley, N. (2017). *Achieving Digital Maturity. Adapting Your Company to a Changing World.* http://sloanreview.mit.edu/digital2017

Korpela, J., Lehmusvaara, A., & Tuominen, M. (2001). An analytic approach to supply chain development. In *Int. J. Production Economics* (Vol. 71).

Melkonyan, A., Krumme, K., Gruchmann, T., Spinler, S., Schumacher, T., & Bleischwitz, R. (2019). Scenario and strategy planning for transformative supply chains within a sustainable economy. *Journal of Cleaner Production*, *231*, 144–160. https://doi.org/10.1016/j.jclepro.2019.05.222

Savastano, M., Cucari, N., Dentale, F., & Ginsberg, A. (2022). The interplay between digital manufacturing and dynamic capabilities: an empirical examination of direct and indirect effects on firm performance. *Journal of Manufacturing Technology Management*, *33*(2), 213–238. https://doi.org/10.1108/JMTM-07-2021-0267

Szukits, Á. (2022). The illusion of data-driven decision making – The mediating effect of digital orientation and controllers' added value in explaining organizational implications of advanced analytics. *Journal of Management Control*, *33*(3), 403–446. https://doi.org/10.1007/s00187-022-00343-w

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509–533.

Teece, D. J. (2020). Hand in glove: Open innovation and the dynamic capabilities framework. *Strategic Management Review*, *1*(2), 233-253.

Zouari, D., Ruel, S., & Viale, L. (2021). Does digitalising the supply chain contribute to its resilience? *International Journal of Physical Distribution and Logistics Management*, *51*(2), 149–180. https://doi.org/10.1108/IJPDLM-01-2020-0038